

# Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

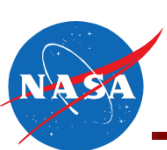
## Korea Visit



May 22-23, 2017

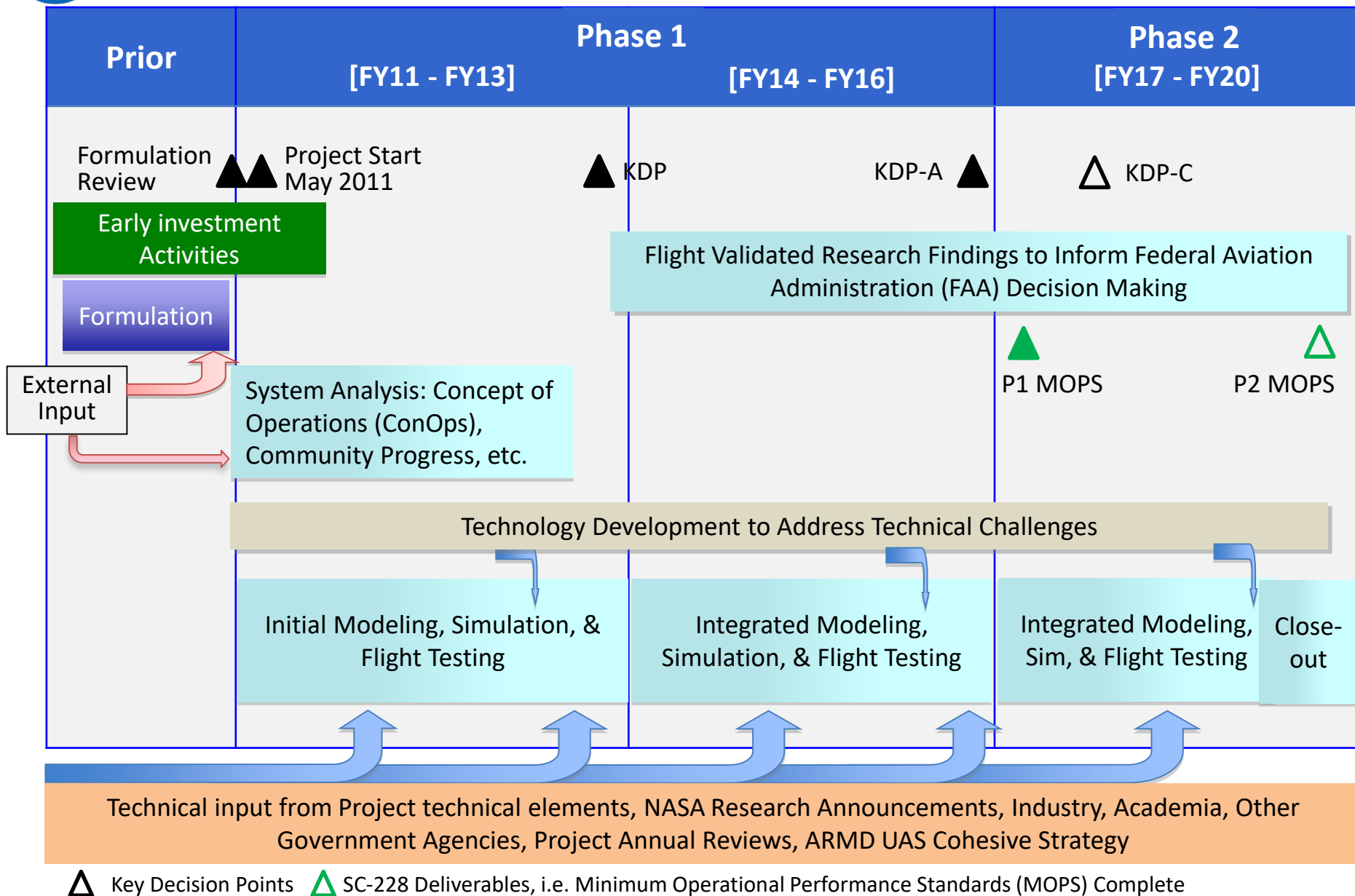
UAS INTEGRATION IN THE NAS

Davis Hackenberg  
Deputy Project Manager



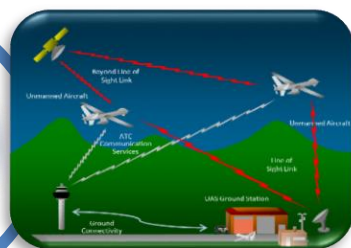
# UAS-NAS Project Lifecycle

Timeframe for impact: 2025

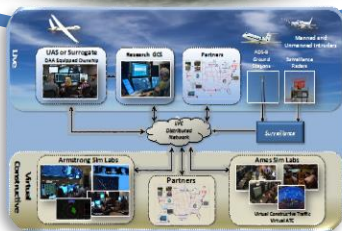


△ Key Decision Points    △ SC-228 Deliverables, i.e. Minimum Operational Performance Standards (MOPS) Complete

Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System

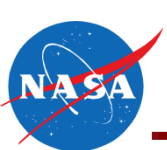


## Technical Challenge-C2: Command and Control (C2)



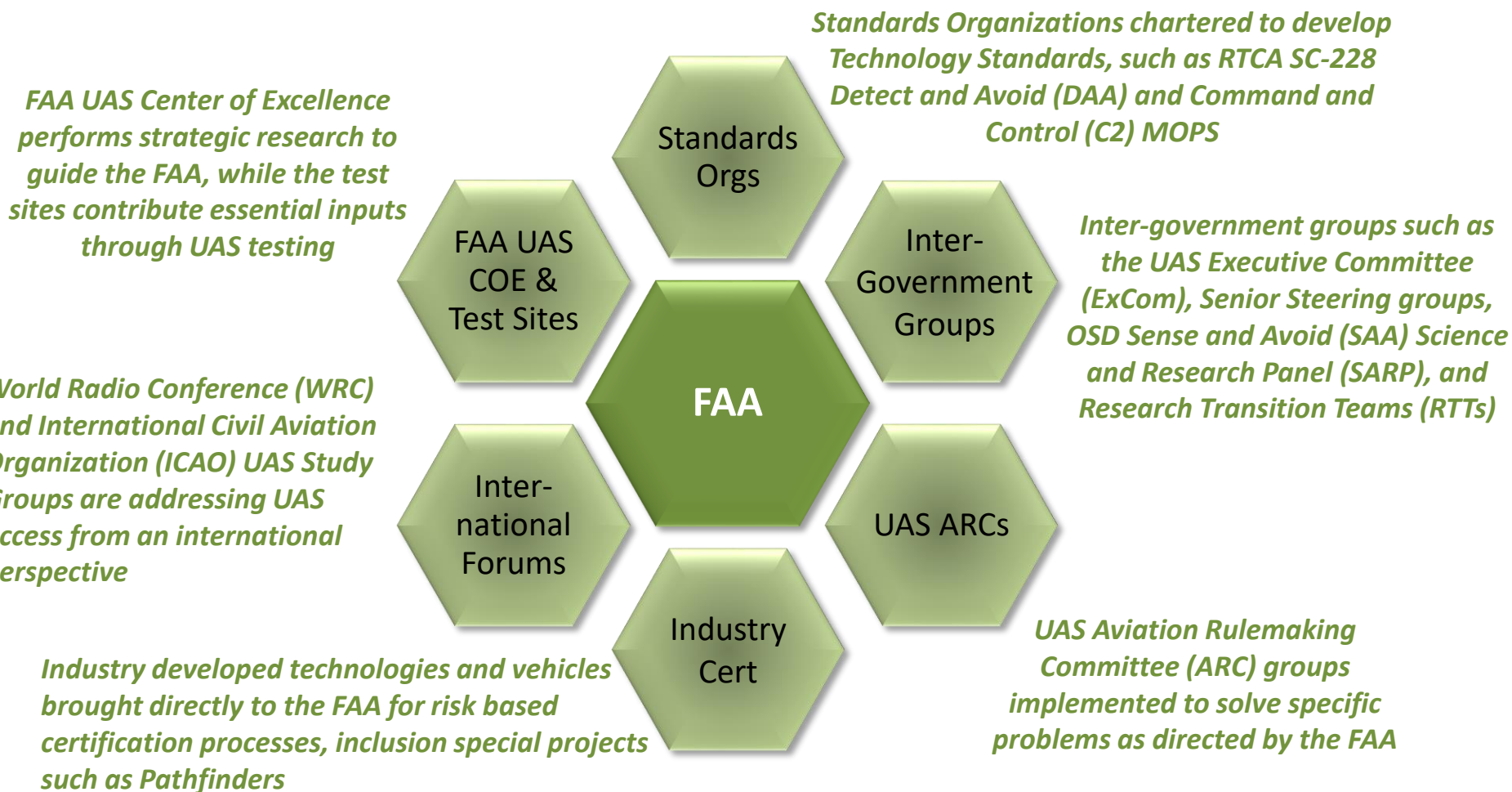
### **Technical Challenge-SIO: System Integration and Operationalization (SIO)**



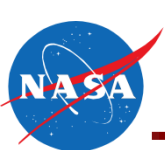


# FAA Organizational Relationships

- The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.



**NASA has a leadership role within many domestic forums and participates in the international forums**



# RTCA SC-228 Phase 1 MOPS Terms of Reference

- RTCA SC-228 Terms of Reference (ToR) defined a path forward to develop Minimum Operational Performance Standards (MOPS)
- Phase 1 MOPS are addressed by UAS-NAS Current (FY14 – FY16) Portfolio
  - Command and Control (C2) Data Link MOPS – Performance Standards for the C2 Data Link using L-Band Terrestrial and C-Band Terrestrial data links
  - Detect and Avoid (DAA) MOPS – Performance standards for transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and perhaps Class G airspace
- SC-228 Deliverables to RTCA PMC
  - C2 and DAA White Papers (Dec 2013) - Assumptions, approach, and core requirements for UAS DAA and C2 Equipment
  - C2, DAA, and Radar MOPS for Verification and Validation (Jul 2015) – Preliminary MOPS Including recommendations for a Verification and Validation test program
  - C2 Final MOPS (Jul 2016)
  - DAA and Radar Final MOPS (Nov 2016)

RTCA Paper No. 100-13/PMC-1089  
May 20, 2013

**TERMS OF REFERENCE**  
**RTCA Special Committee 228**  
**Minimum Performance Standards for Unmanned Aircraft Systems**

REQUESTORS:

Organization	Person
AVS	Jim Williams

SPECIAL COMMITTEE LEADERSHIP:

Position	Name	Affiliation	Telephone	email	Change
Co-Chair	George Ligler	Consultant to PMEI	301-983-4388	gligler@pmet.com	(list to change in name)
Co-Chair	Paul McDuffee	Insitu Inc.	208-493-6409	paul.mcduffee@insitu.com	
DFO	Steve Van Trees	FAA	202-385-4635	stephen.vantrees@faa.gov	
Secretary	Gary Furr	Engility Corporation	809-485-4254	Gary.c.furr@faa.gov	

BACKGROUND:

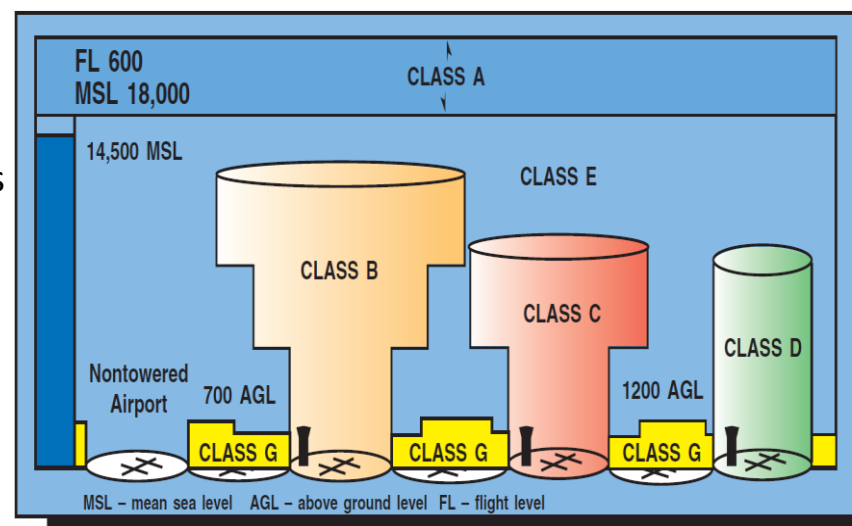
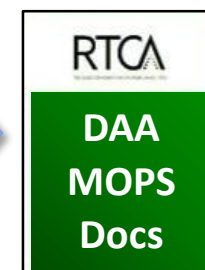
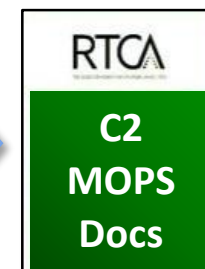
Unmanned aircraft have the potential to allow civil, public, commercial, and government agencies to increase efficiency, save money, enhance safety, and even save lives. A broad range of applications and services seek to integrate these platforms into non-segregated airspace.

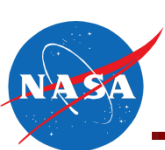
In order to safely integrate these platforms into non-segregated airspace, both a robust Detect and Avoid (DAA) and robust and secure Command and Control (C2) Data Link capability need to be established.

The Federal Aviation Administration (FAA) established the Unmanned Aircraft Systems Integration Office to integrate Unmanned Aircraft Systems (UAS) safely and efficiently into the National Airspace System (NAS).

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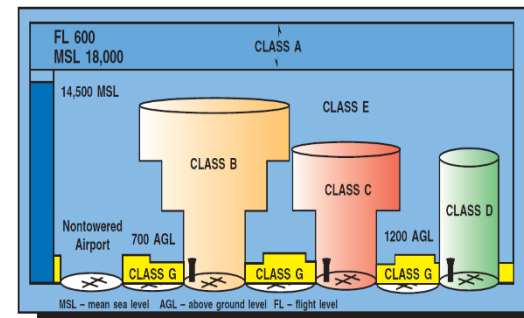
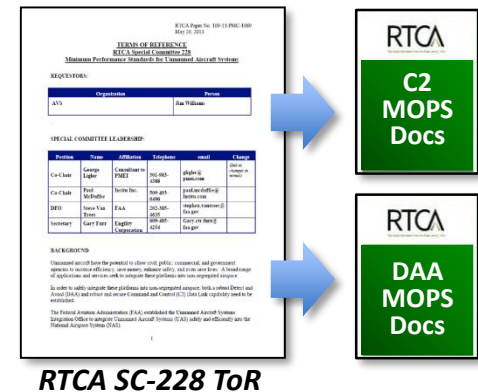
RTCA SC-228 ToR





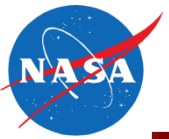
# RTCA SC-228 P2 MOPS Terms of Reference

- RTCA SC-228 Terms of Reference (ToR) defined a path forward to develop Minimum Operational Performance Standards (MOPS)
  - Phase 1 MOPS were addressed by UAS-NAS (FY14 – FY16) Portfolio
  - Phase 2 MOPS included in the original ToR, but had several TBDs
    - ToR development team established to ensure DAA & C2 scope broad enough to fully enable the operating environments relevant UAS were expected to leverage (e.g. Manned Like IFR and Tweeners)
- Phase 2 MOPS ToR Scope
  - C2: Use of SATCOM in multiple bands and terrestrial extensions as a C2 Data Link to support UAS and address networking interoperability standards for both terrestrial and satellite systems
  - DAA: Extended UAS operations in Class D, E, and G, airspace, and applicability to a broad range of civil UAS capable of operations Beyond Visual Line of Sight (BVLOS)
- SC-228 Final Documents



Phase 1 (To Be Published 2016)	Phase 2	
• C2 Terrestrial Datalink MOPS	• C2 SATCOM & Network MASPS (Oct 2017 & Jan 2019)	• Ground Based Primary Radar MOPS & DAA MOPS Rev A (Sep 2019)
• DAA MOPS	• C2 SATCOM Data Link MOPS (Jul 2019*)	• Non-Cooperative Sensor MOPS & DAA MOPS Rev B (Sep 2020)
• DAA Air to Air Radar MOPS	• C2 Terrestrial Data Link MOPS Rev A (Jul 2020)	

\* Date under discussion within RTCA SC-228



# UAS-NAS Project Value Proposition

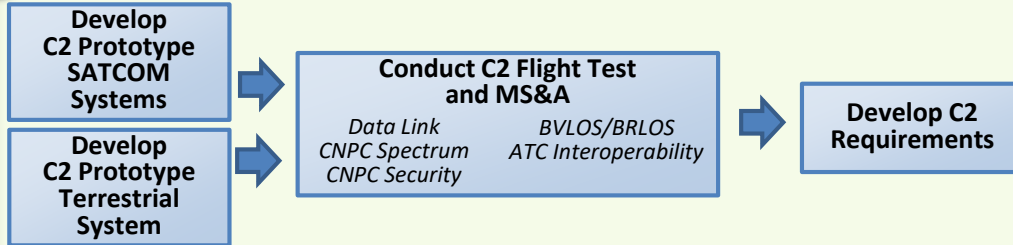
## NASA UAS-NAS Project Activities

## Key Products

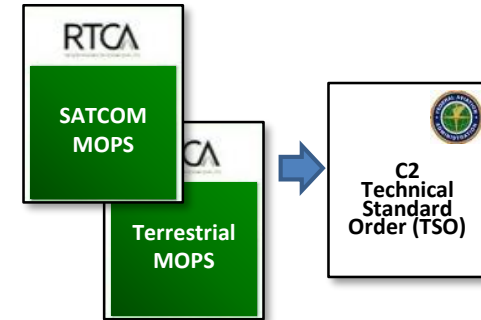
## Resultant Outcomes

TC  
C2

### *C2 Performance Standards*

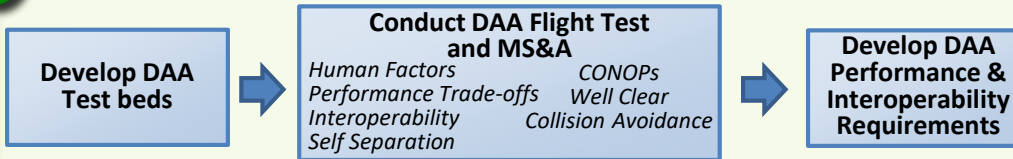


*C2 Performance Requirements to inform C2 MOPS*

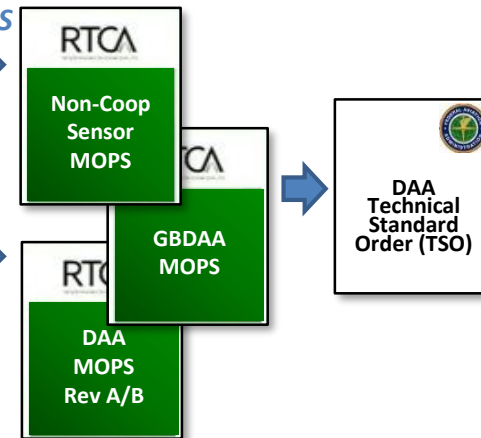


TC  
DAA

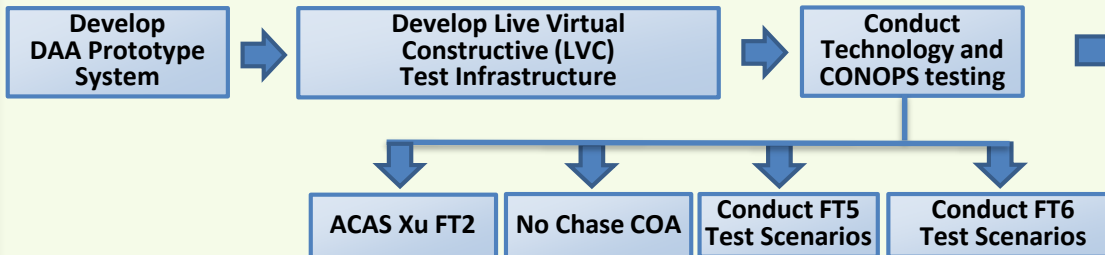
### *DAA Performance Standards*



*DAA Performance Requirements to inform DAA MOPS*



### *Integrated Test & Evaluation*

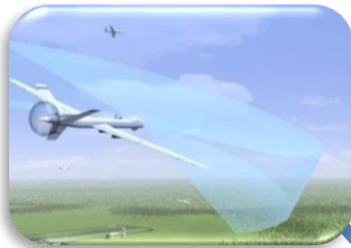


*Re-usable Test Infrastructure*

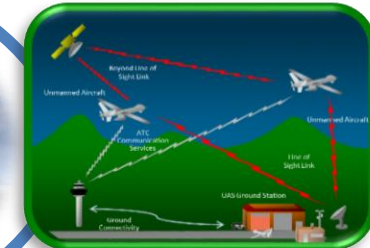
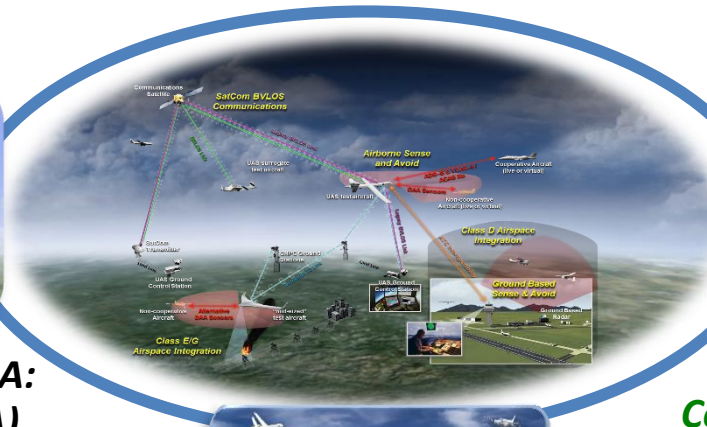
# UAS Satcom and Terrestrial Command and Control

# Project Goal

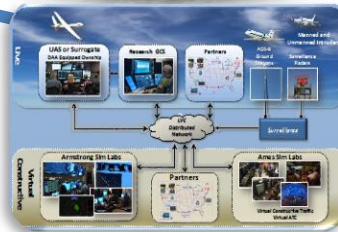
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System



### Technical Challenge-DAA: Detect and Avoid (DAA)



## Technical Challenge-C2: Command and Control (C2)

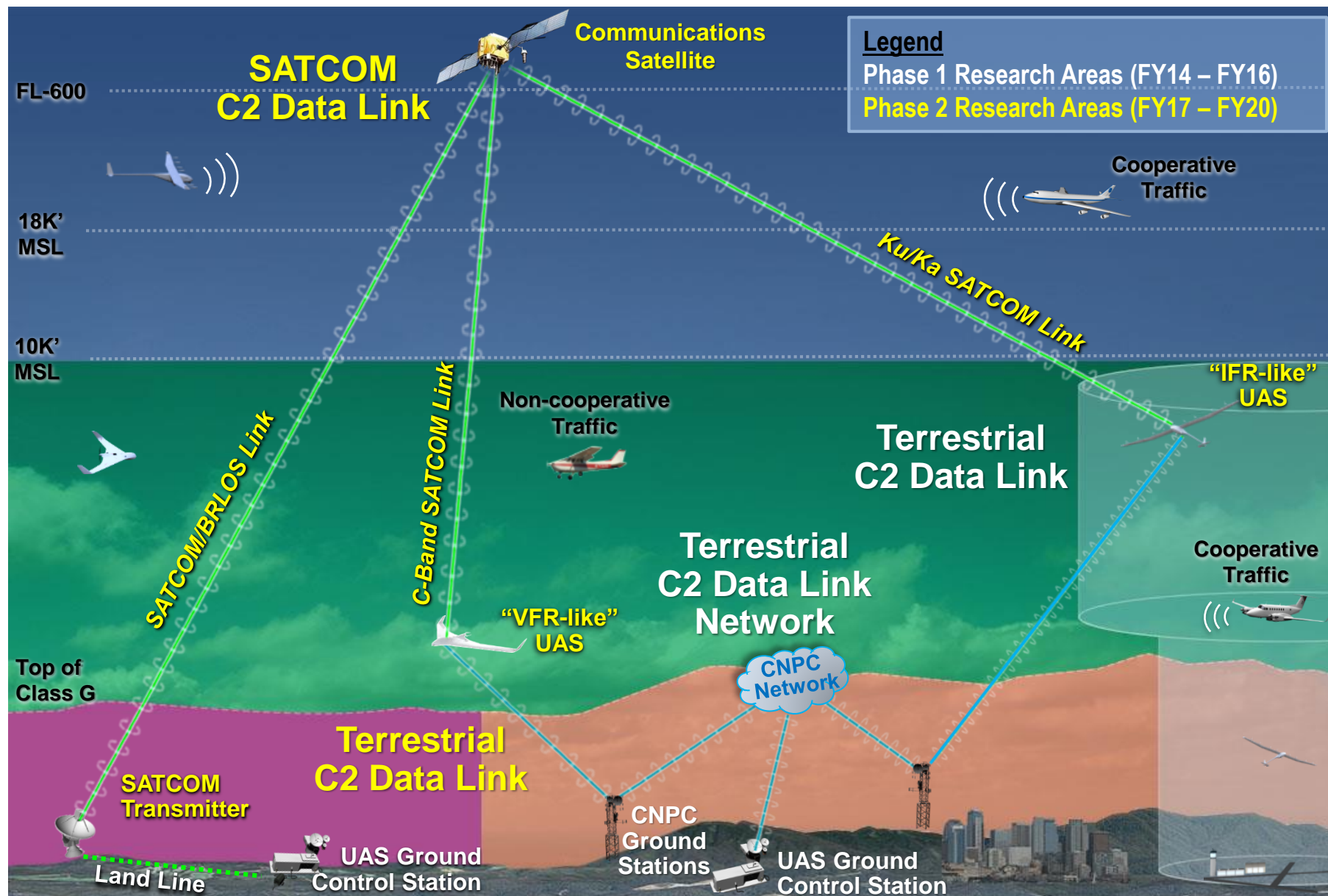


### **Technical Challenge-SIO: System Integration and Operationalization (SIO)**



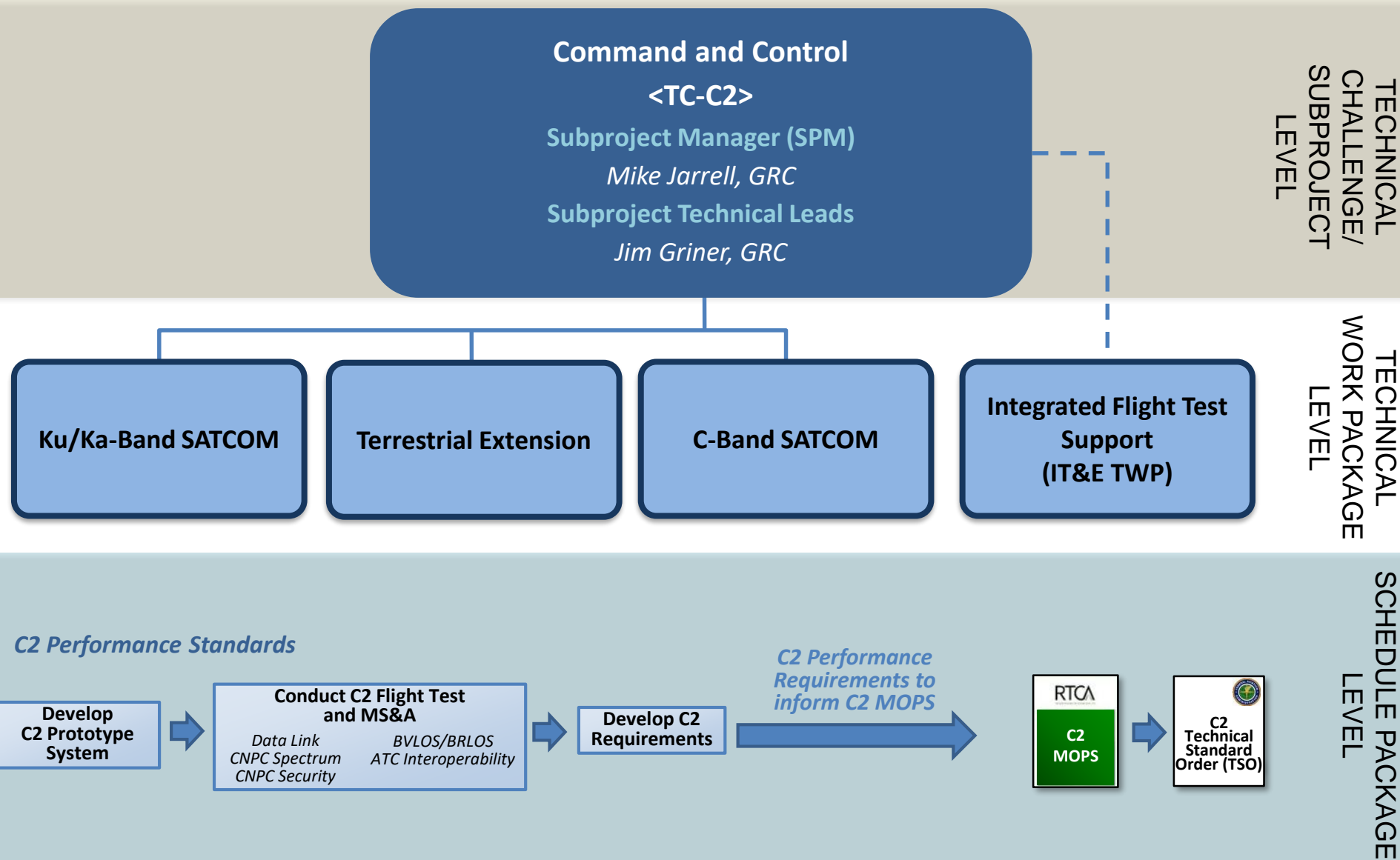


# UAS Satcom and Terrestrial Command and Control Operating Environments (OE)





# C2 Subproject Structure for Project Phase 2



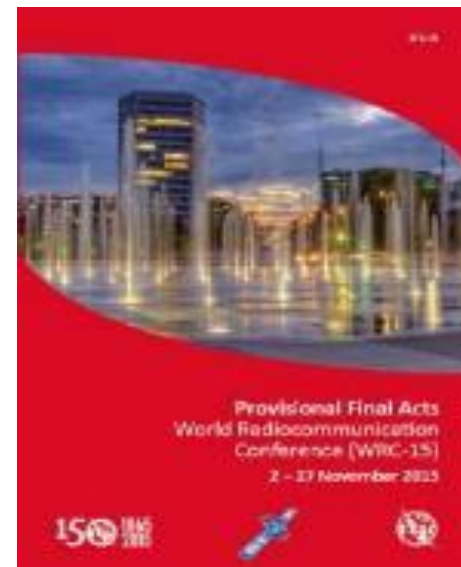


# Recent Accomplishments: C2 Phase 1 MOPS

## Spectrum Compatibility Analysis

Objective: Develop data and rationale to obtain appropriate frequency spectrum allocations to enable the safe and efficient operation of UAS in the NAS

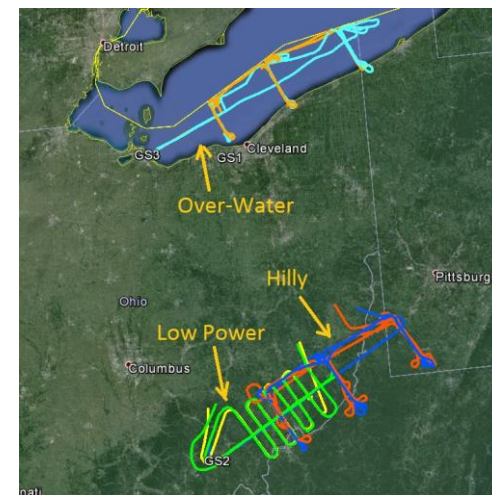
Accomplishment: NASA conducted sharing study results delivered at the 2015 World Radiocommunication Conference (WRC-15) to support Ku & Ka Band frequency Allocations



## Verify and Validate C2 MOPS Requirements

Objective: Analyze the performance of fifth generation Control and Non-Payload Communication System (CNPC) prototypes

Accomplishment: Utilized Gen-5 radios at three CNPC ground stations and onboard GRC S-3B aircraft in order to collect data for performance in two relevant environments





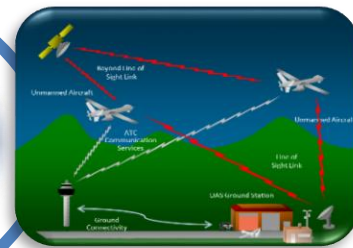
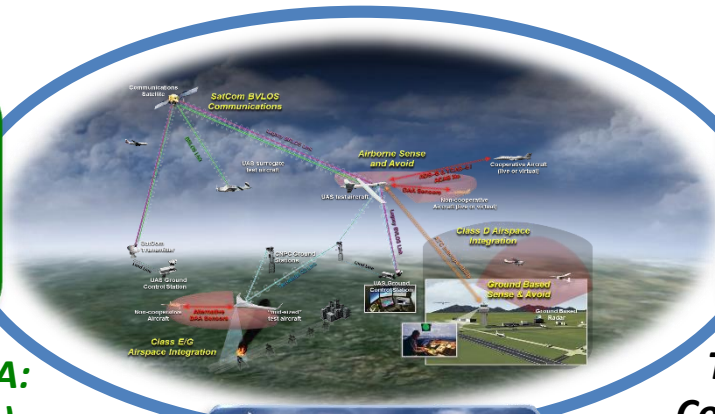
## UAS Detect and Avoid Operational Concepts and Technologies

### Project Goal

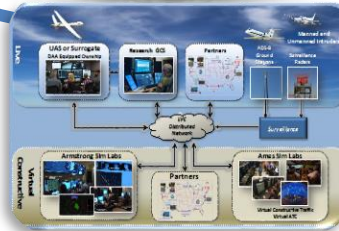
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System



**Technical Challenge-DAA:**  
**Detect and Avoid (DAA)**



**Technical Challenge-C2:**  
**Command and Control (C2)**

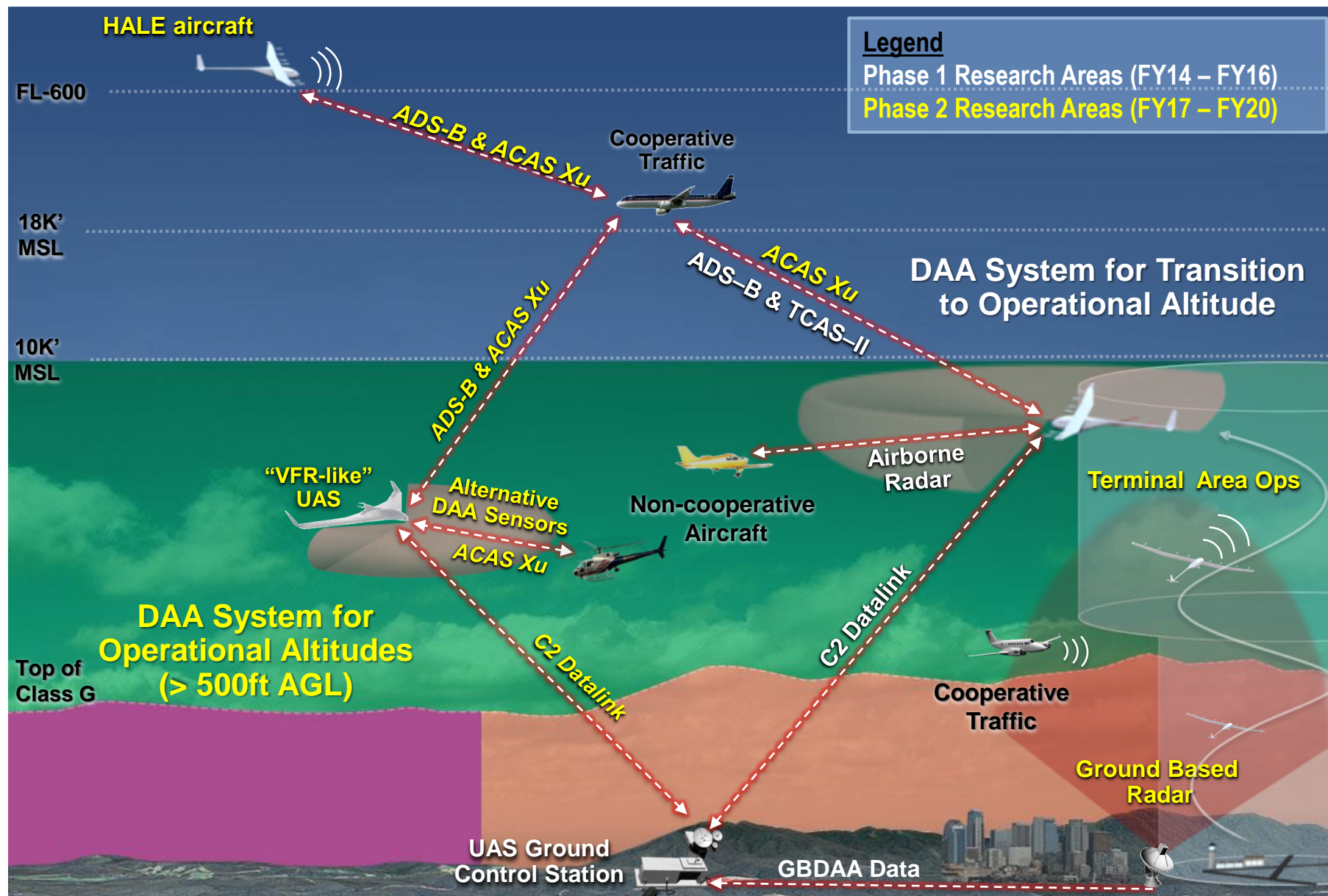


**Technical Challenge-SIO:**  
**System Integration and Operationalization (SIO)**





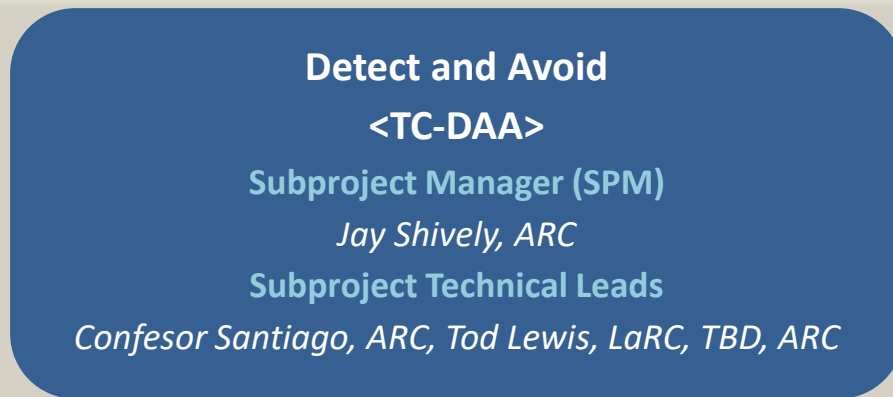
# Detect and Avoid (DAA) Performance Standard Operating Environments (OE)



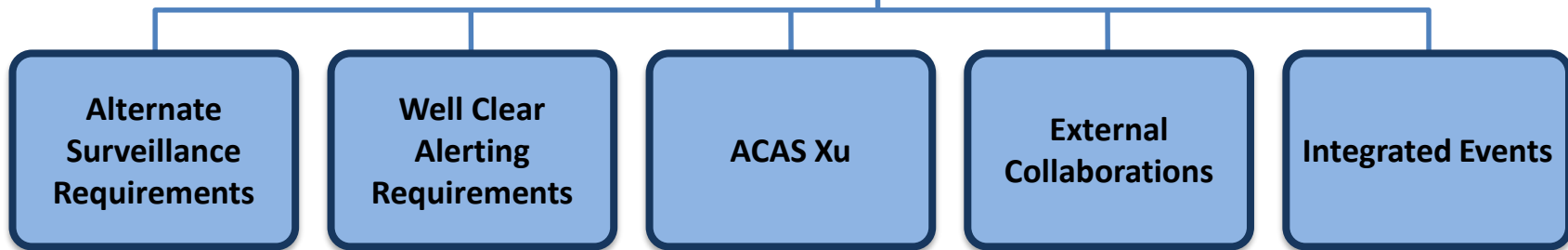


# DAA Subproject Structure for Project Phase 2

TECHNICAL  
CHALLENGE/  
SUBPROJECT  
LEVEL

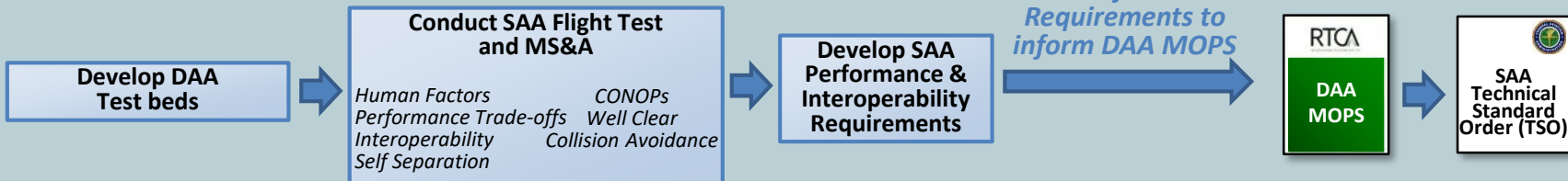


TECHNICAL  
WORK PACKAGE  
LEVEL



SCHEDULE PACKAGE  
LEVEL

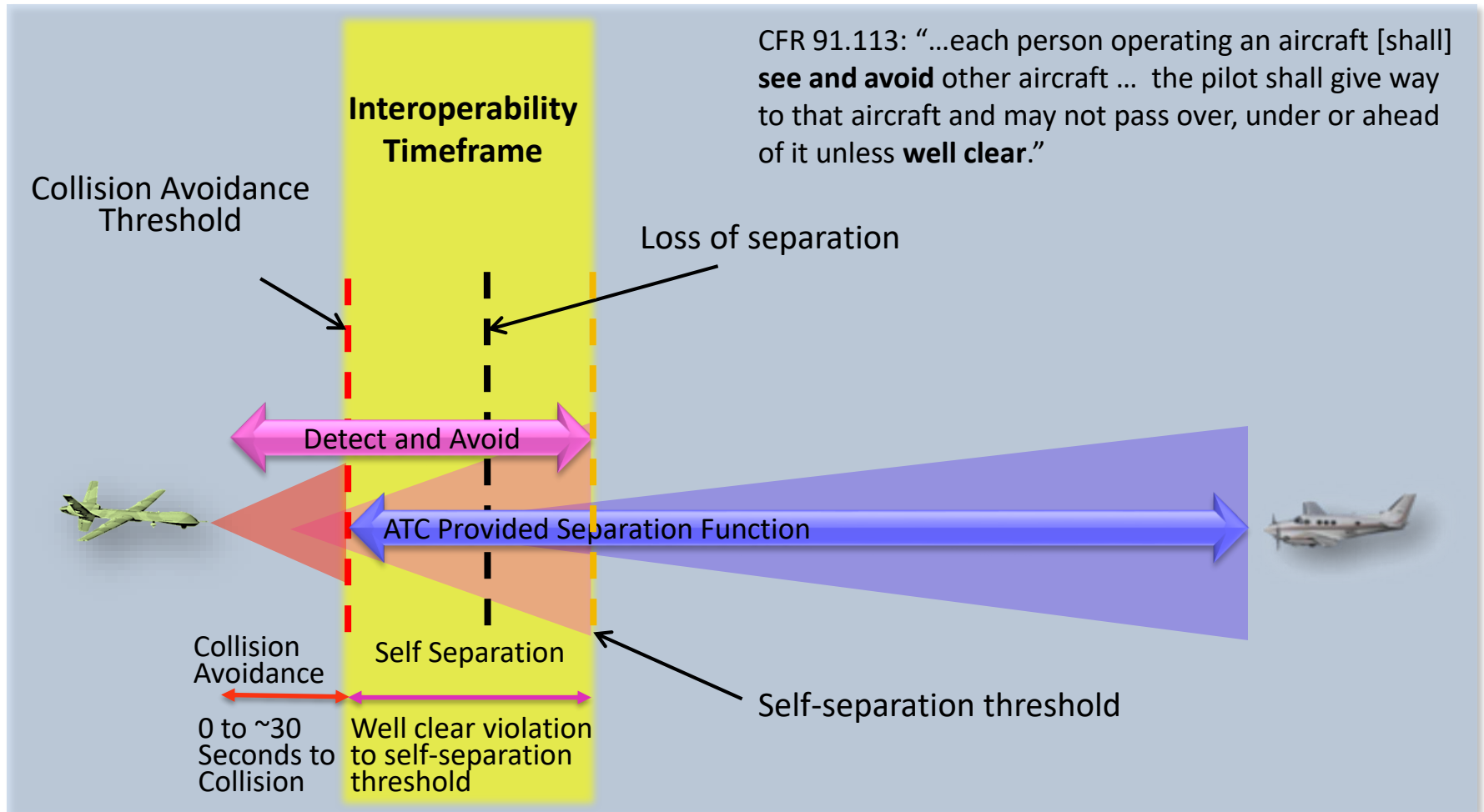
## SAA Performance Standards





# Separation from other Aircraft

## Detect-and-Avoid



\*Time horizons of applicability are not to scale

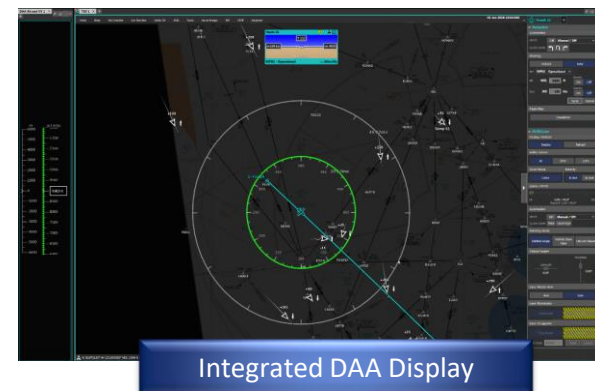


# Recent Accomplishments: DAA Phase 1 MOPS

## Human Systems Integration “Part Task 6”

Objective: Conduct final V&V activity in support of the SC-228 DAA human machine interface requirements for displays, alerting, and guidance

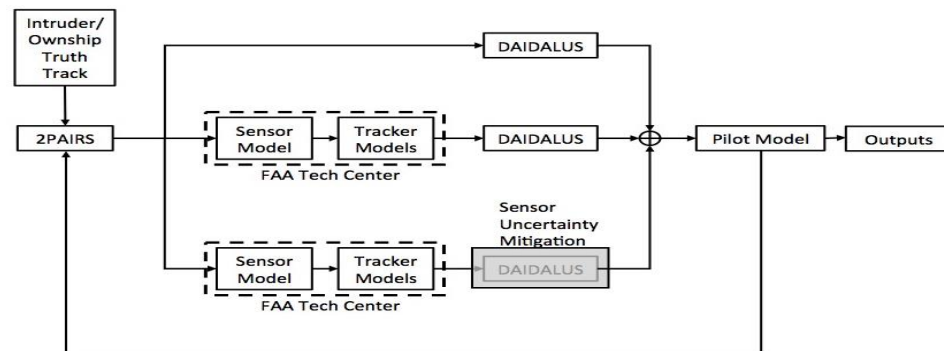
Accomplishment: Verified pilot performance against minimum requirements, re-evaluated performance differences between a standalone and integrated DAA displays



## DAA End to End V&V

Objective: Verify and Validate (V&V) a MOPS-representative Detect and Avoid (DAA) system in an End-to-End simulation environment representative of the MOPS

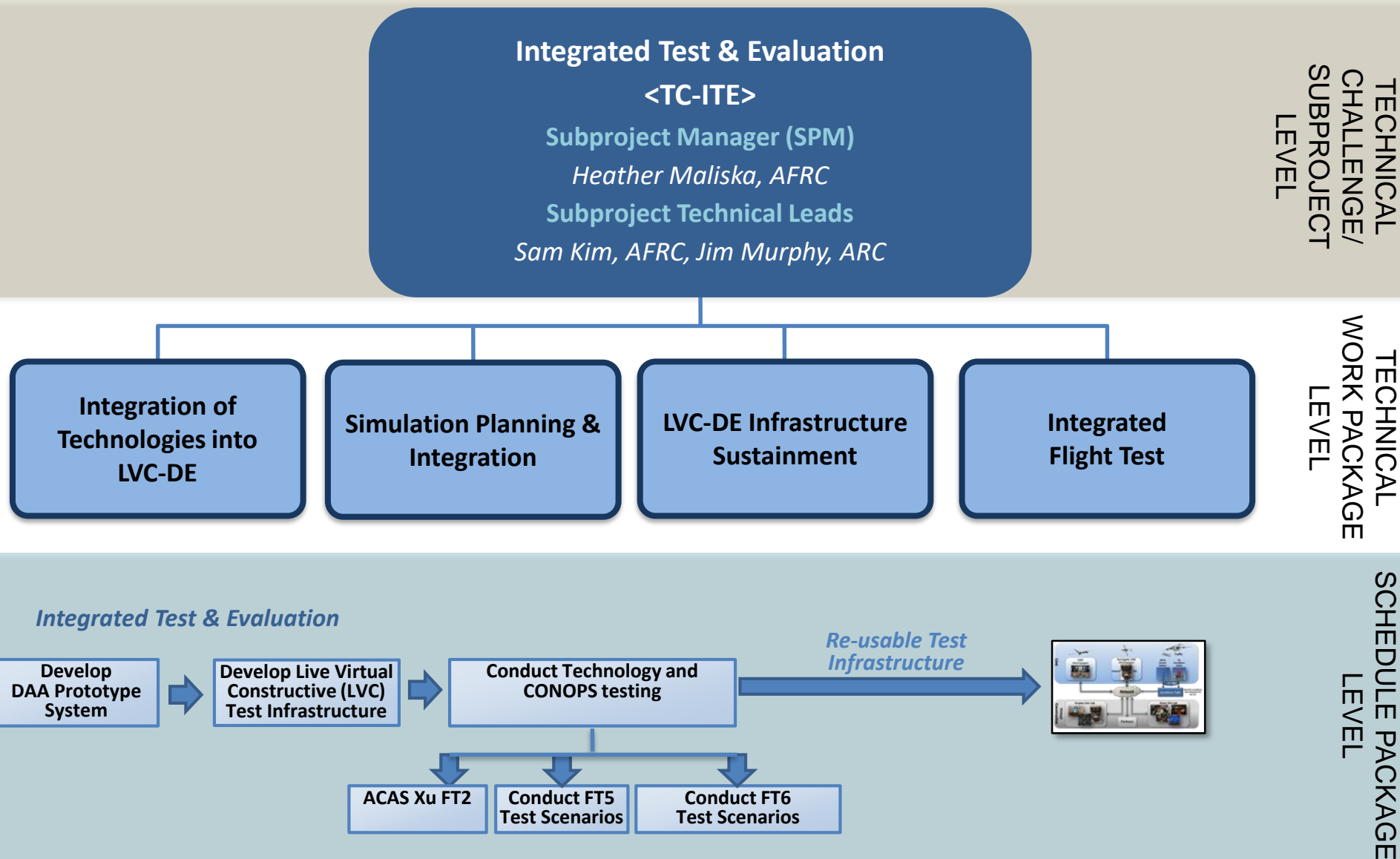
Accomplishment: Final closed-loop, pilot (model)-in-the-loop, end-to-end simulation evaluation of MOPS leveraging encounter sets from MOPS test cases & MIT/LL NAS encounter model



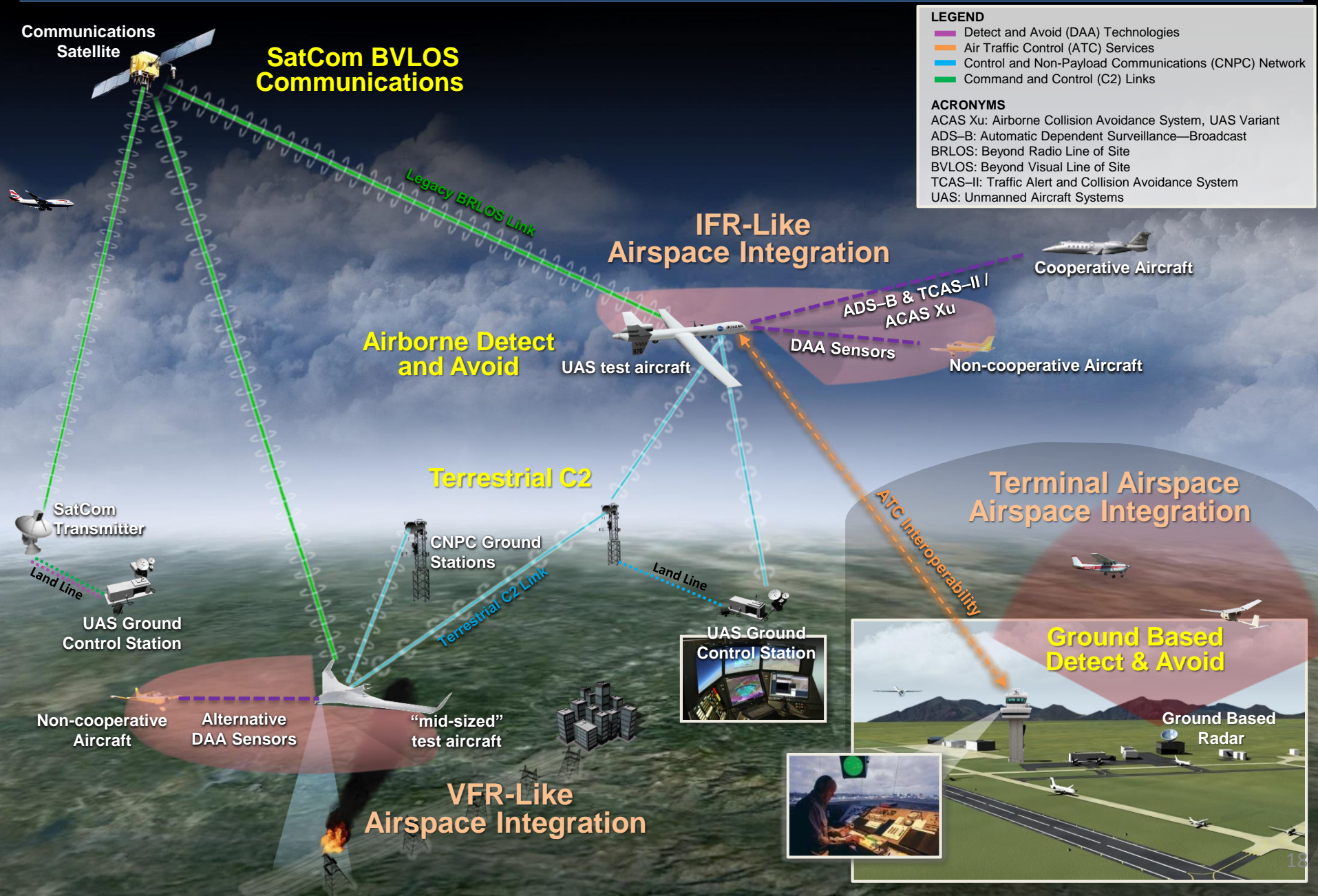




# IT&E Subproject Structure for Project Phase 2



# UAS-NAS Project - DAA and C2 Operational View Representation

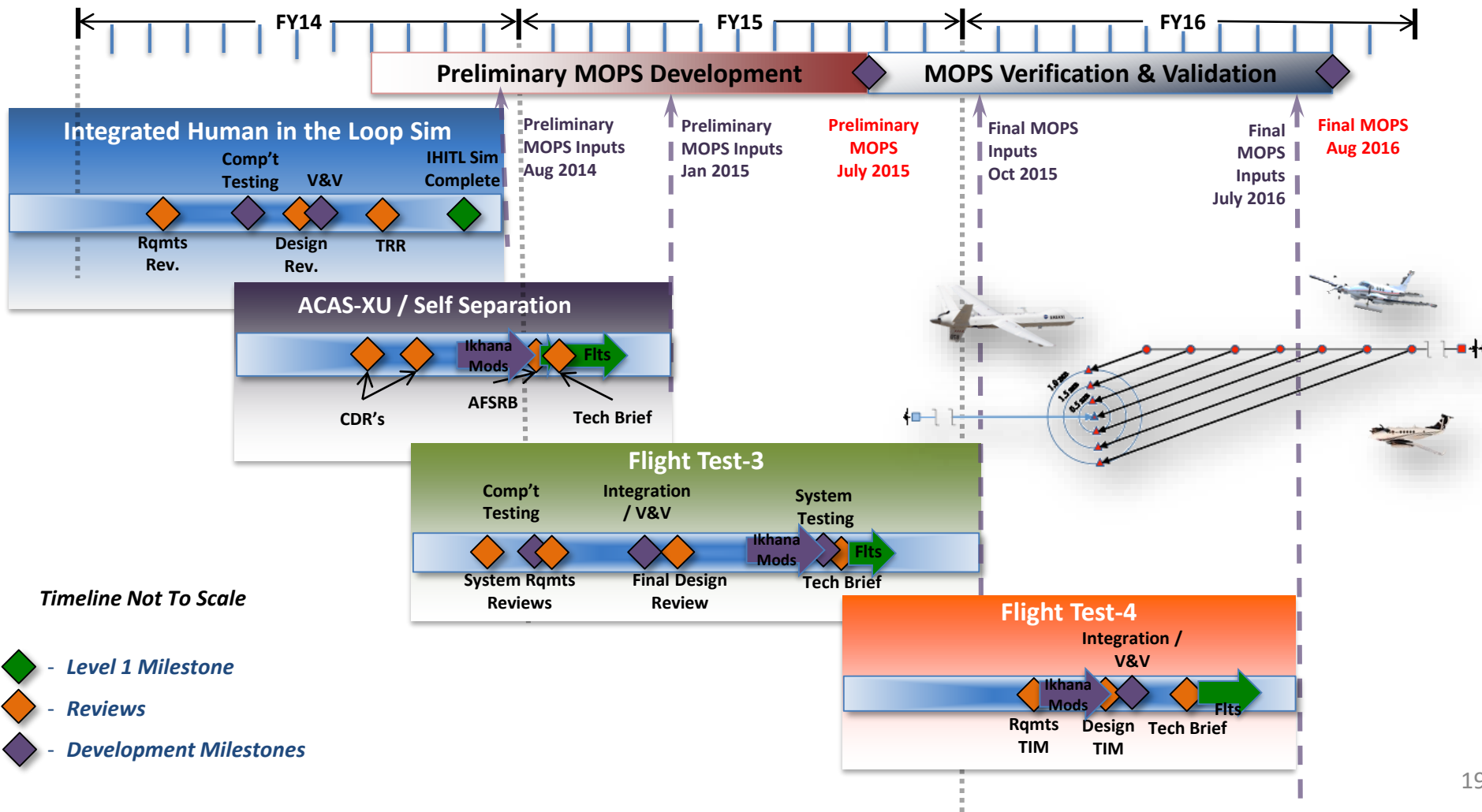




# UAS-NAS Build-up of IT&E Infrastructure for P1 Flight Test

## Risk Reduction Approach To Integrated Test Flow

- Each test built upon the previous and reduced future risk.
- Lessons learned applied from one test to the next.





# Recent Accomplishments: DAA Phase 1 MOPS

## Integrated Test and Evaluation FT4

Objective:

- Conduct Flight Test Series 4 integrating the latest SSI algorithms, HSI displays, and active test aircraft sensors using the Live, Virtual, Constructive test environment
- Document the performance of the test infrastructure in meeting the flight test requirements

Accomplishment: FT4 successfully completed on 6/30/2016

- 2 system checkout and 19 data collection flight tests
- 11 weeks (April 12 - June 30)
- 321 air-to-air encounters



LVC



FT4 Flight Assets



Flight card encounter



DAA alerting and maneuver guidance

Scripted Encounters



SAF Mission Control Room



LVC Lab

Flight Test Execution

Final DAA MOPS scheduled to be released through RTCA in December 2016





# IT&E Capabilities:

## Providing the Infrastructure for Flight Testing

- Ownship – Ikhana
  - Build-up of DAA system (radar/ADS-B/TCAS) to meet researcher requirements
  - Logged over 190 hours of flight time with Ikhana for ACAS Xu, FT3 and FT4 data collection flights
- Intruder aircraft – 6 total aircraft
  - Met researcher objectives to represent many classes of aircraft
    - Slow-Speed, Mid-Speed, High-Speed
    - Cooperative vs. Non-Cooperative
    - Small, medium, large radar cross section
  - Equipped 4 aircraft with required sensors
  - Coordinated 25 crew members from 3 organizations
    - NASA, Air Force, Honeywell
- Flight Test Stats
  - ACAS Xu: 9 flights, 170 encounters flown (1 intruder)
  - FT3: 11 flights, 212 encounters flown (multiple intruders)
  - FT4: 19 flights, 321 encounters flown (up to 4 intruders/enc.)

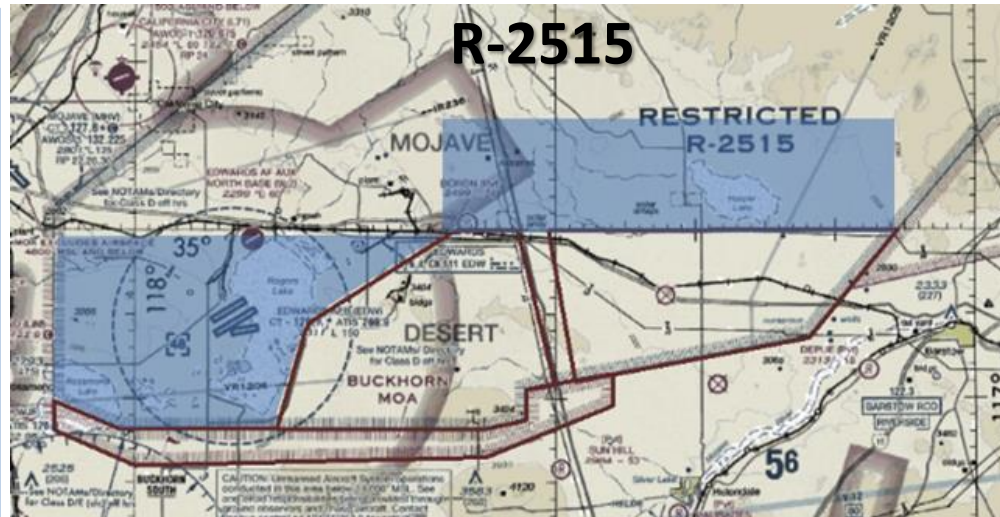




## Encounter Design and Range Coordination

### Airspace Planning

- Primarily Mercury Spin, 4 Corners & Buckhorn MOA (red outline)
- 1,000 ft AGL (4.2K ft) to 20K ft MSL
- Extensions (west / north) may be requested real time for encounters that need the additional airspace
- Ops outside of test area (blue shaded areas) are planned to be performed early (before 0800) when airspace is relatively empty
- Operations between 0600 and 0700 are under Joshua control and have less geographical constraints

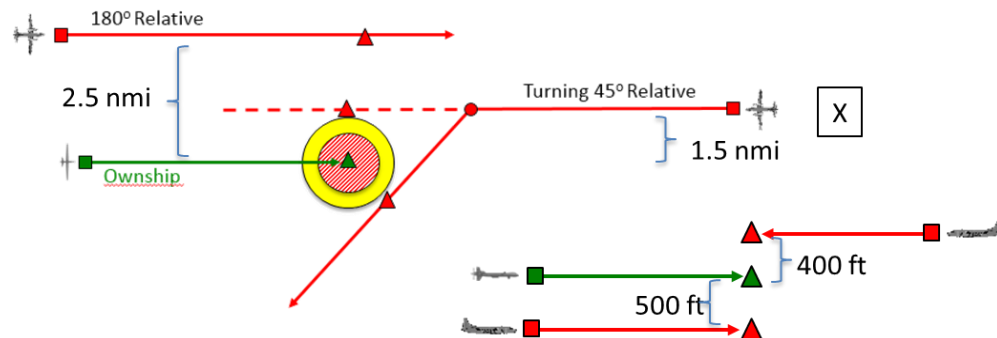


### Airspace Extensions (Blue Shaded Areas)

- Conducted early 0600-0800 preferably
- Pre-coordinated 24-48 hours in advance
- Requested real-time with SPORT (after 0700)

### • Coordination with Edwards Range

- Coordination of range/operating area borders and UAS keep out zones.
- Ikhana must remain within R-2515 at all times.
- Intruder aircraft can use Buckhorn MOA, plus areas shaded in blue



### • Encounter design accomplished by operations working group with researchers and partners.

- Encounter requirements coordinated with System Safety Working Group to ensure flight safety.
- Mitigations designed into flight test planning (safe separation, training, testing, offsets, procedures, etc..)





# Summary

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- UAS-NAS Project has developed robust capabilities supporting initial developments of DAA and C2 Technologies
- Significant work is remaining to lead the community towards ensuring DAA and C2 technology are interoperable with the entire National Airspace System.
- The project is dedicated to driving the community towards robust and innovative solutions that apply to DAA, C2, and other necessary vehicle technologies